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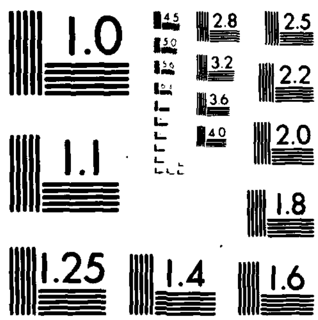

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DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

WAVE RESISTANCE OF HIGH LENGTH-TO-BEAM SURFACE EFFECTS SHIPS

by

Richard T. Van Eseltine

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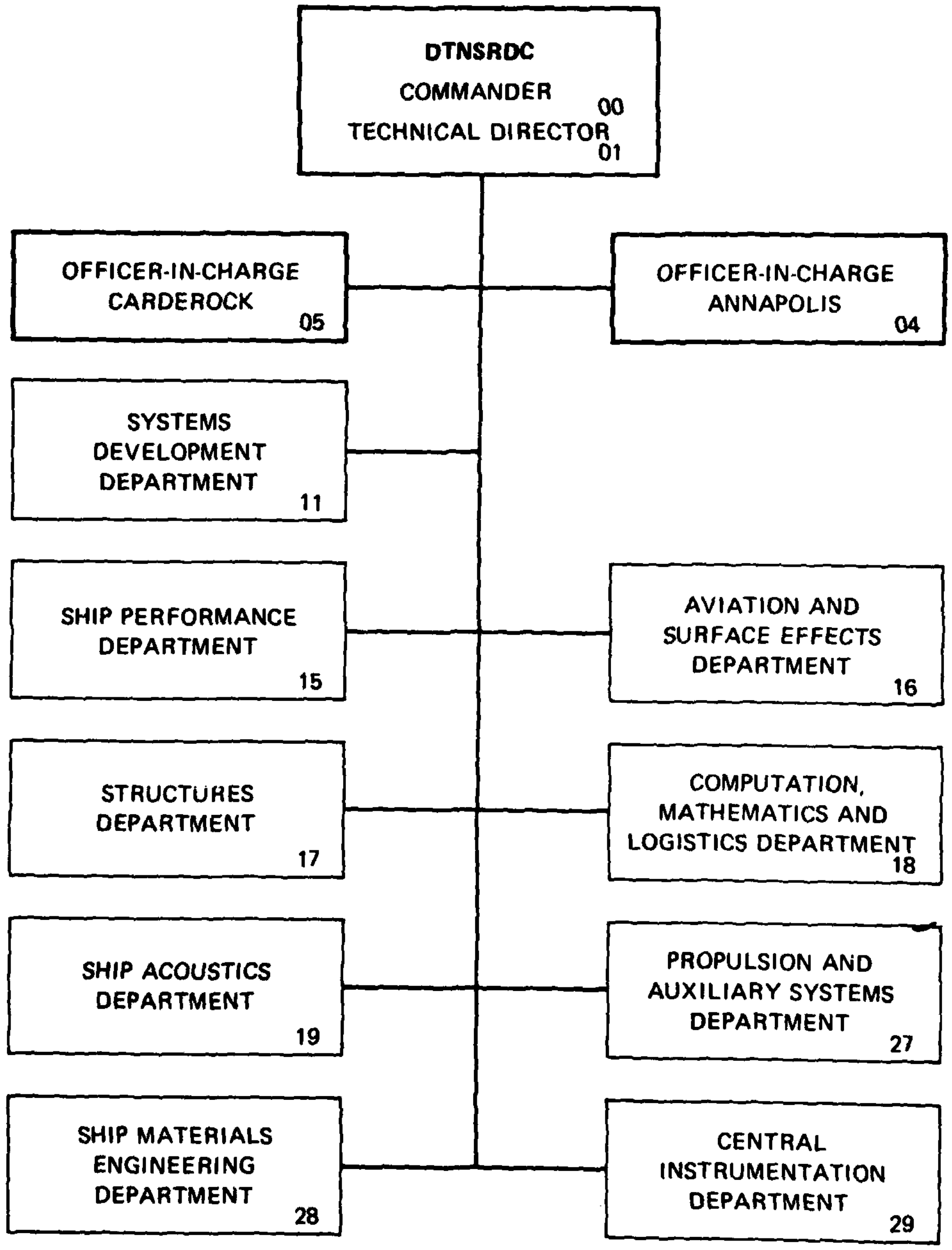

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The ACVWAV computer program is used to investigate the wave resistance experienced by a pressure distribution moving at constant speed. Wave resistance coefficients at constant weight and pressure for various length-to-beam ratios are presented. Surface elevations are also computed.

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ABSTRACT

The ACVWAV computer program is used to investigate the wave resistance experienced by a pressure distribution moving at constant speed. Wave resistance coefficients at constant weight and pressure for various length-to-beam ratios are presented. Surface elevations are also computed.

ADMINISTRATIVE INFORMATION

This work was sponsored by PMS304 under Special SES Projects, Task Area S0308SH001, Task 19587, Work Unit 1-1630-072.

INTRODUCTION

Recently there has been an interest in high length-to-beam multipurpose transport surface effects ships. The ACVWAV program can be used to aid in determining the resistance characteristics of such ships. It was used in this study to compute the wave resistance and surface elevations of a pressure distribution moving at constant speed U over calm water for some high length-to-beam ratios. This study is an example of how numerical techniques can aid in predicting the hydrodynamic performance characteristics of proposed ships.

ACVWAV PROGRAM

The ACVWAV program computes the transient hydrodynamics of a pressure distribution moving over a free surface. Steady state results can be obtained by integrating over a long time until the transient effects around the pressure distribution are no longer significant.

A Fourier Series method, originally developed by Haussling and Van Eseltine [1,2], is used in the ACVWAV program. The velocity potential, surface elevation, and pressure distribution are expressed as a set of Fourier Series which satisfy, except for the initial and free-surface boundary conditions, the linear governing equations for transient free-surface flows. The Fourier coefficients are chosen to satisfy the initial and free-surface boundary conditions, which results in a set of ordinary differential equations that can be solved analytically. The integrals involved in the solution can be solved analytically or numerically, depending on the shape and movement of the pressure. From the Fourier coefficients, the velocity potential, surface elevations, and wave resistance can be computed.

GEOMETRY OF THE PRESSURE DISTRIBUTION

The pressure distribution is rectangular with length L and beam b. Figure 1 shows the coordinate systems of the computational region and the pressure distribution. The coordinate system (x^*,z^*)

moves with the pressure distribution.

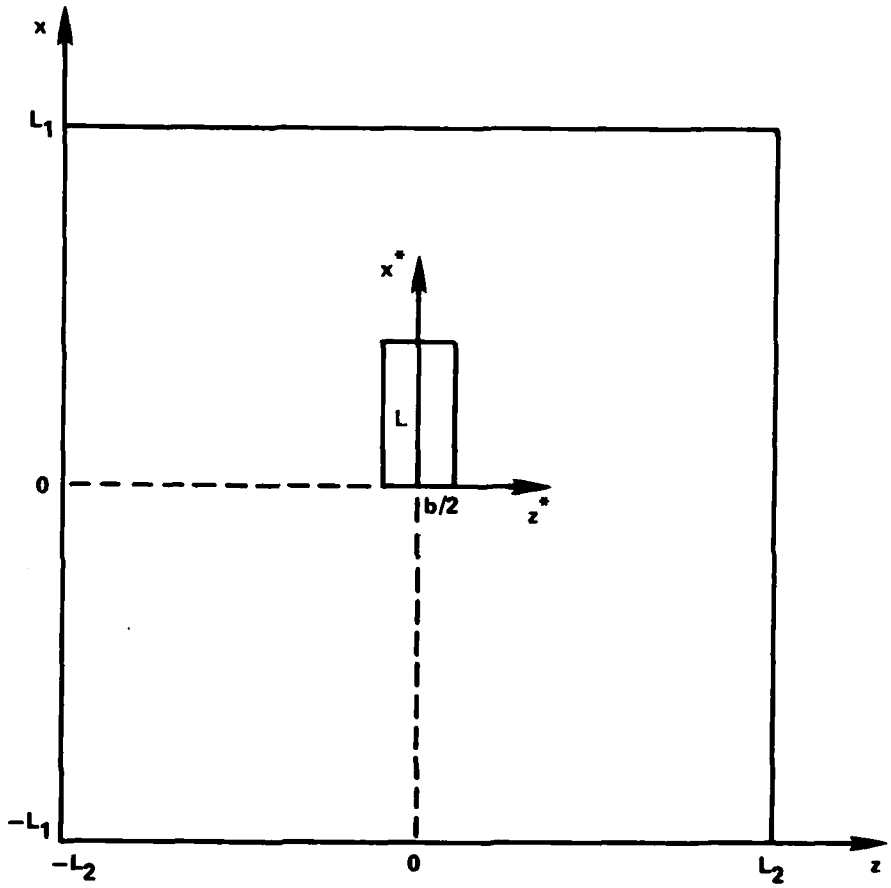

Figure 1 - Computational Region

For this study, the pressure distribution has the form

$$p(x^*,z^*) = p_1(x^*)p_2(z^*)P$$

where

$$
P_1(x^*) = \begin{cases} [1+\sin(\pi x^*/(2a_1))]/2 & -a_1 \le x^* \le a_1 \\ 1 & a_1 < x^* \le (L-a_1) \\ [1-\sin(\pi(x^*-L)/(2a_1))]/2 & (L-a_1) < x^* \le (L+a_1) \\ 0 & \text{otherwise} \end{cases}
$$

$$
P_2(z^*) = \begin{cases} [1+\sin(\pi(z^*+b/2)/(2a_2))]/2 & (-b/2-a_2) \le z^* \le (-b/2+a_2) \\ 1 & (-b/2+a_2) < z^* \le (b/2-a_2) \\ [1-\sin(\pi(z^*-b/2)/(2a_2))]/2 & (b/2-a_2) < z^* \le (b/2+a_2) \\ 0 & \text{otherwise} \end{cases}
$$

and P is the maximum pressure. The parameters a_1 and a_2 control the fall-off of the pressure in the x^* and z^* directions, respectively. Figure 2 shows the spatial distribution of the pressure for b=75

feet, L=375 feet, and a_1=a_2=30 feet.

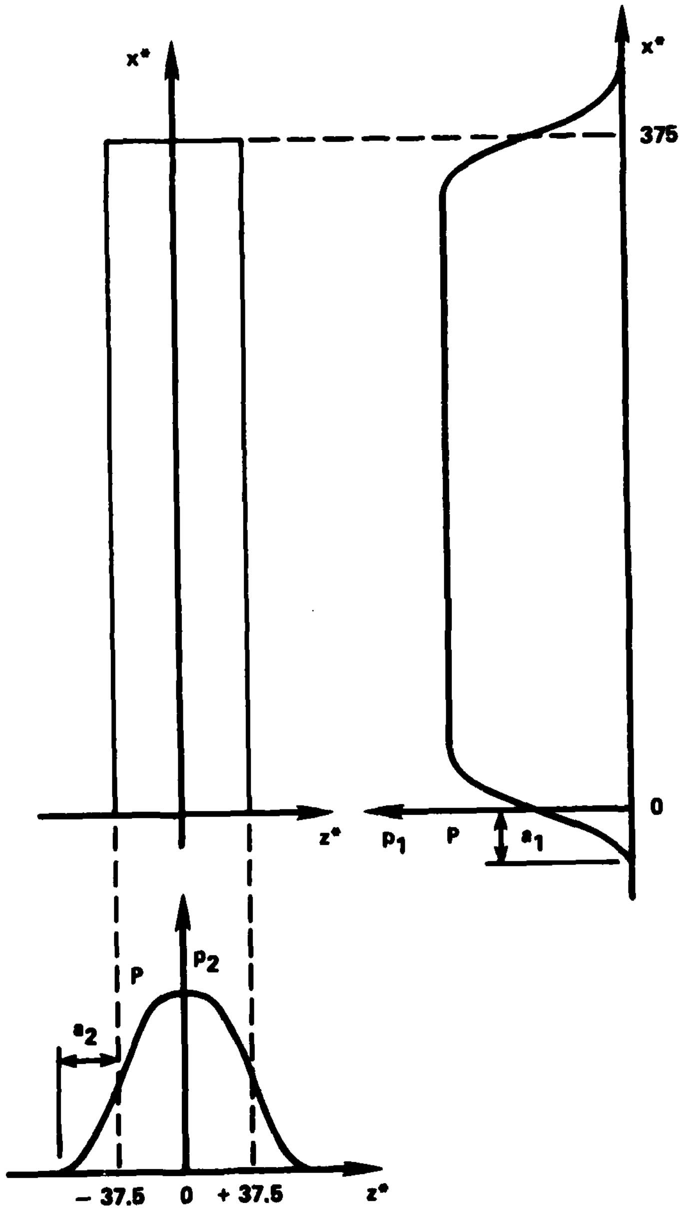

Figure 2 - Spatial distribution of the pressure for b=75 ft., L=375 ft., and a_1=a_2=30 ft.

DETERMINATION OF REGION SIZE

The accuracy of the computations depends on the size of the region and on the number of Fourier coefficients representing it. L_1 and L_2 (Figure 1) must be large enough that the interactions among image pressure distributions are negligible. The number of Fourier coefficients in the x and z directions, M and N respectively, must be sufficiently large to resolve all the dominant wave frequencies. Numerical experiments were done to assure accurate results. Two cases were chosen which would represent the extremes of the cases to be computed. The resistance coefficient at constant pressure R_p (defined in the next section) was printed at several times to ensure that steady state had been reached and that there were no disturbances from the image pressure distributions. The number of Fourier coefficients were varied from M=N=210 to M=N=110 to ensure that the dominant wave frequencies were resolved. For both cases, L_1 and L_2 were chosen to be 10 times L. Table 1 shows the R_p for L/b=10. From time step 41 to 45 the pressure distribution moved approximately twice its length and the resistance coefficient has changed by less than 1%. There is less than a 2.5% change in R_p from M=N=210 to M=N=110.

Table 1 - R_p for L/b of 10

Time Step / M × N	41	43	45
210 × 210	0.45567	0.45556	0.45336
185 × 185	0.45559	0.45550	0.45349
160 × 160	0.45330	0.45321	0.45134
135 × 135	0.44674	0.44663	0.44556
110 × 110	0.44431	0.44425	0.44377

Table 2 shows R_p for L/b=5. From time step 41 to 45 the pressure distribution moved approximately 2.8 times its length. There is a small change in R_p (3.5%) during this time. From M=N=210 to M=N=110, R_p changes by less than 1%.

Table 2 - R_p for L/b of 5

Time Step / M × N	41	43	45
210 × 210	0.66481	0.65310	0.64149
185 × 185	0.66482	0.65310	0.64150
160 × 160	0.66477	0.65305	0.64145
135 × 135	0.66423	0.65250	0.64090
110 × 110	0.66276	0.65098	0.63940

On the basis of these experiments, 210 Fourier coefficients in the x and z directions were chosen with L_1 and L_2 being 10 times the length of the pressure. All cases were computed to the 45th time step.

RESULTS AND CONCLUSIONS

For this study a speed of 45 knots, a beam of 75 feet, and a_1 and a_2 of 30 feet were used. The wave resistance coefficients for twenty cases were computed for length-to-beam ratios from 5 to 10. Two wave resistance coefficients were computed for each case. The resistance coefficient for constant pressure is defined as

$$R_p = R/(2P^2 b/\rho g)$$

where R is the resistance, P is the maximum pressure, b is the beam, ρ is the density of water, g is the gravitational acceleration, and L is the characteristic length of the pressure distribution. This resistance coefficient is useful if the pressure is held constant as the length of the ship is changed. If the ship is to support a given weight, however, the pressure will decrease as the length is increased, and it is more meaningful to consider the resistance coefficient for constant weight defined as

$$R_w = R/(2PLb)$$

Table 3 gives the resistance coefficients for the cases computed and Figure 3 gives them in graphical form. R_p decreases from L/b of 5 to 6.25 and then remains relatively constant until L/b of 8, where it begins to slowly decrease again. R_w decreases

rapidly from L/b of 5 to 6.25 where a change in the rate of decline begins. At L/b of 8 R_w starts to decrease approximately linearly.

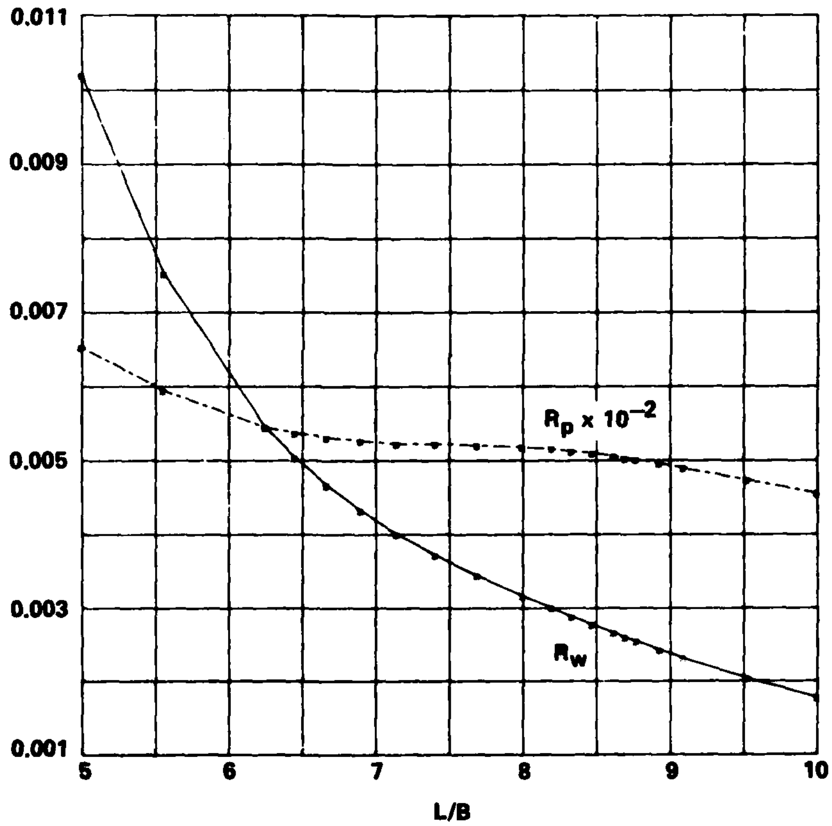

Figure 3 - Resistance coefficients of L/b of 5 to 10.

Table 3 - Resistance coefficients for L/b of 5 to 10

L/b	R_p	R_w	L/b	R_p	R_w
5.000	0.652	0.01019	8.197	0.515	0.00299
5.556	0.594	0.00752	8.333	0.511	0.00288
6.250	0.544	0.00544	8.475	0.509	0.00277
6.452	0.536	0.00503	8.621	0.505	0.00265
6.667	0.530	0.00466	8.696	0.502	0.00259
6.897	0.526	0.00432	8.772	0.501	0.00254
7.143	0.522	0.00399	8.929	0.495	0.00243
7.407	0.522	0.00371	9.091	0.489	0.00231
7.692	0.519	0.00343	9.524	0.473	0.00204
8.000	0.517	0.00315	10.000	0.454	0.00177

Surface elevations for three length-to-beam ratios were computed. All length scales were nondimensionalized by the length of the pressure distribution (L). Figures 4, 5, and 6 show the contours of the surface elevations generated by the pressure distribution for L/b of 5, 6.667, and 10, respectively. In all cases the values of elevations associated with the contours plotted are ±.002, ±.006, ±.010, ..., where solid contours are positive and dashed contours are negative elevations.

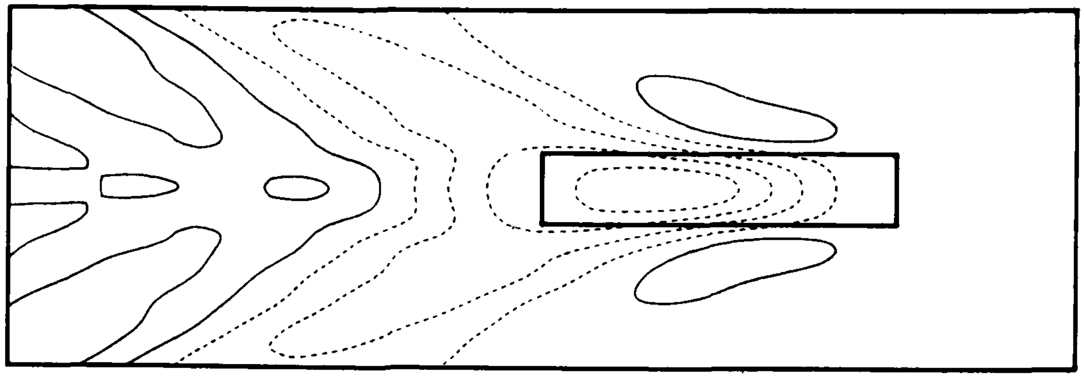

Figure 4 - Surface elevations for L/b of 5.

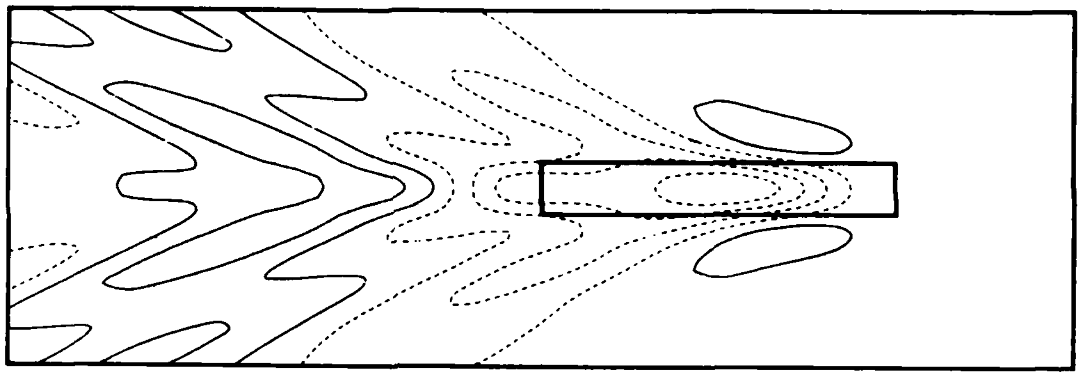

Figure 5 - Surface elevations for L/b of 6.667.

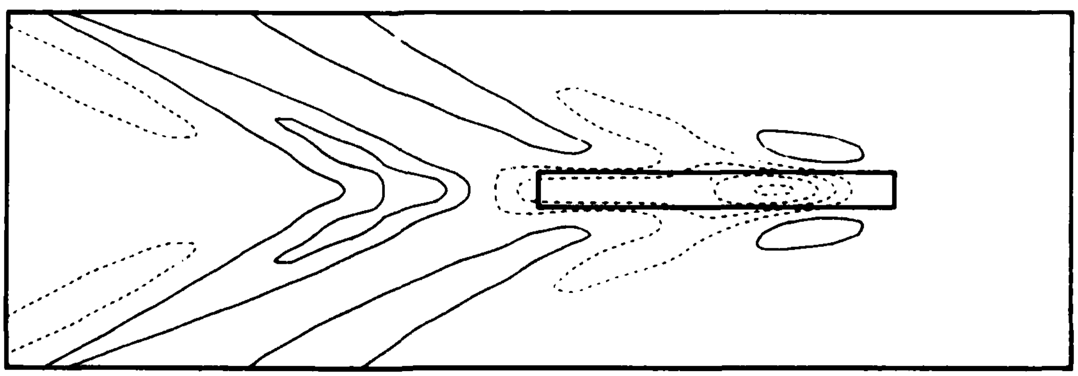

Figure 6 - Surface elevations for L/b of 10.

The use of the ACVWAV program in predicting wave resistances for the multipurpose transport surface effect ships demonstrates its potential for aiding in the design of such ships. A more realistic fall-off for the pressure distribution needs to be chosen, although it is doubtful that the trends of the resistance coefficient curves would change. There is also a need to vary the speed of the pressure distribution to obtain a more complete picture of the wave resistance characteristics.

ACKNOWLEDGMENT

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